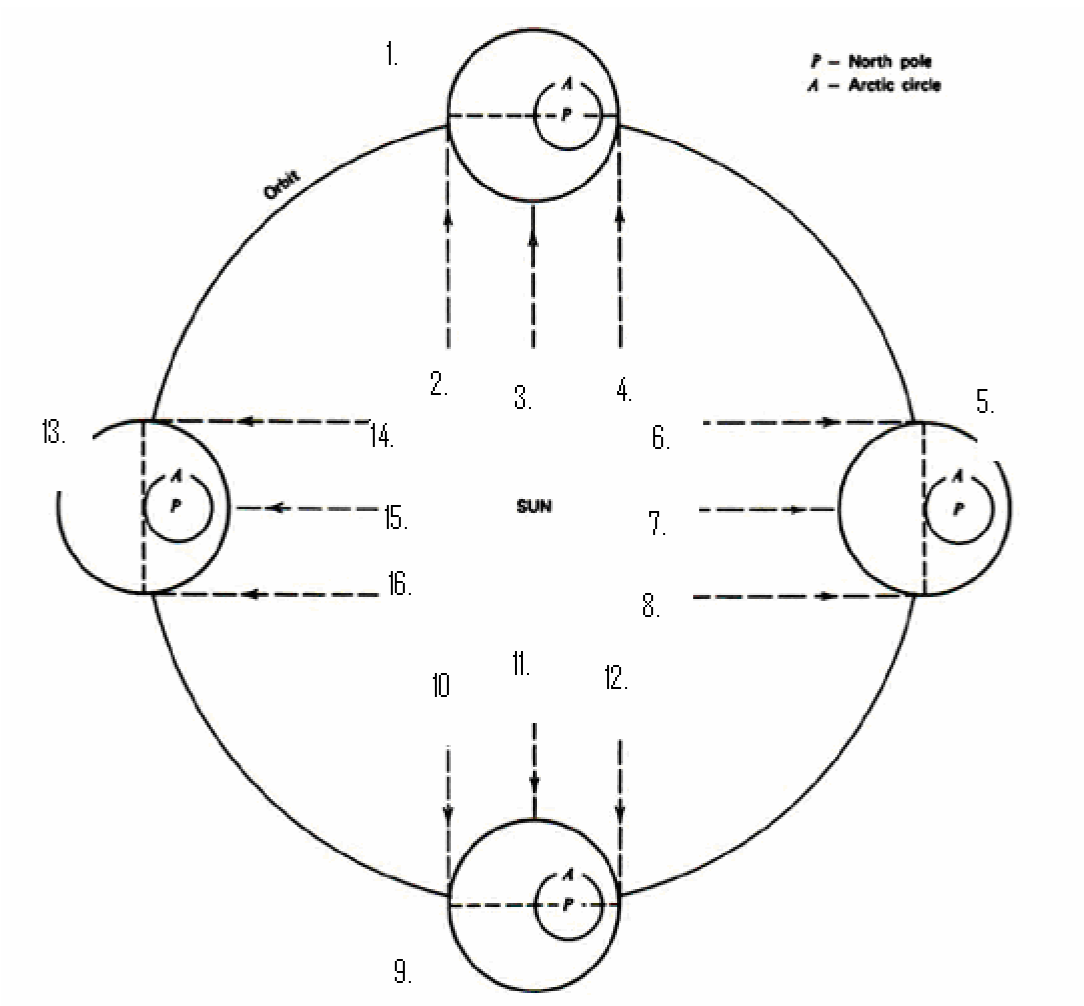
Name:______________________

**Equinoxes and Solstices**

The diagram below represents a view of the earth from a point about the plane of orbit (plane of the ecliptic). The dashed line halving each globe represents the circle of illumination.

1. Label each equinox and solstice and give the date.
2. Add arrows to show direction of earth rotation and revolution.
3. Shade in the dark half of each globe.
4. Mark the points of noon, midnight, sunrise, and sunset with the letters N, M, R, and S, respectively.



# The Annual Cycle of Insolation

The annual cycle of insolation at a given location on the globe depends on two factors: the latitude at which the observer is located and the sun's changing angle above the horizon at noon.

On graph A, you will show the sun's changing angle throughout the year. The angle used on the vertical scale of the graph is known as the sun's declination, which can be thought of as the global parallel of latitude over which the sun at noon is in the zenith position (or straight up in the sky). This condition occurs at the equator twice yearly on the dates of the equinoxes. The sun is directly overhead at noon over the tropic of cancer (23.5° N) on the summer solstice and directly overhead at the tropic of Capricorn (23.5° S) on the winter solstice.

The table below gives the sun's declination angle at 10-day intervals throughout the year. Plot these points on graph A and connect them with a smooth curve. Label the horizontal line of 0° as "Equator." Draw horizontal lines at 23.5° N and S, label them "Tropic of Cancer" and "Tropic of Capricorn."

*Table A Sun's Declination Throughout the Year*

| Date | Declination (degrees) | Date | Declination (degrees) |
|---|---|---|---|
| Jan 1 | 23 S | Jul 10 | 22½ |
| 10 | 22 | 20 | 21 |
| 20 | 20 | 30 | 18½ |
| 30 | 17½ | Aug 10 | 16 |
| Feb 10 | 15 | 20 | 12½ |
| 20 | 11 | 30 | 9 |
| Mar 1 | 8 | Sep 10 | 5 |
| 10 | 4½ | 20 | 1½ |
| 20 | ½ | 30 | 2½ S |
| 30 | 3½ N | Oct 10 | 6½ |
| Apr 10 | 7½ | 20 | 10 |
| 20 | 11 | 30 | 13½ |
| 30 | 14½ | Nov 10 | 17 |
| May 10 | 17 | 20 | 19½ |
| 20 | 20 | 30 | 21½ |
| 30 | 22 | Dec 10 | 23½ |
| Jun 10 | 23 | 20 | 23½ |
| 20 | 23½ | | |
| 30 | 23 | | |

**The Intensity of Insolation**

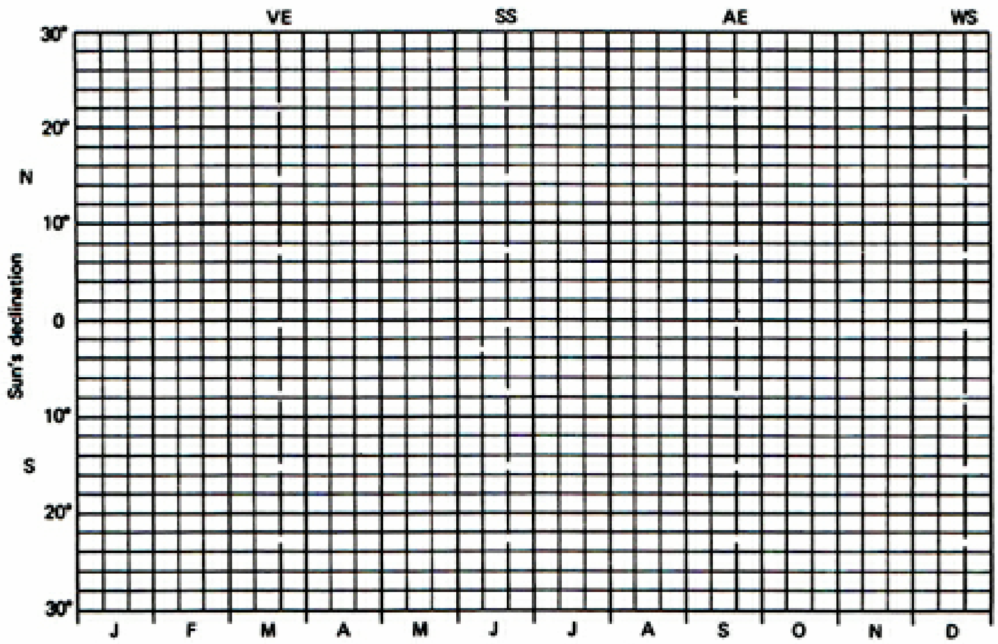
The intensity of Insolation throughout the year is given in the table below. The value of one unit used in this table is 889 gram calories per square centimeter, or 889 Langleys. The Langley has been replaced by watts per square meter, but the curve you get when you graph them will look the same in either unit. On the graph labeled B, plot these monthly values for the following latitudes: 0° (equator), 20° N, 40° S, 60°N, and 90°N. Enter the data point in the middle of the month as shown on the partially drawn line for 60°N. Connect the points with a smooth curve and label the latitude.

***Table B** Insolation Throughout the Year*

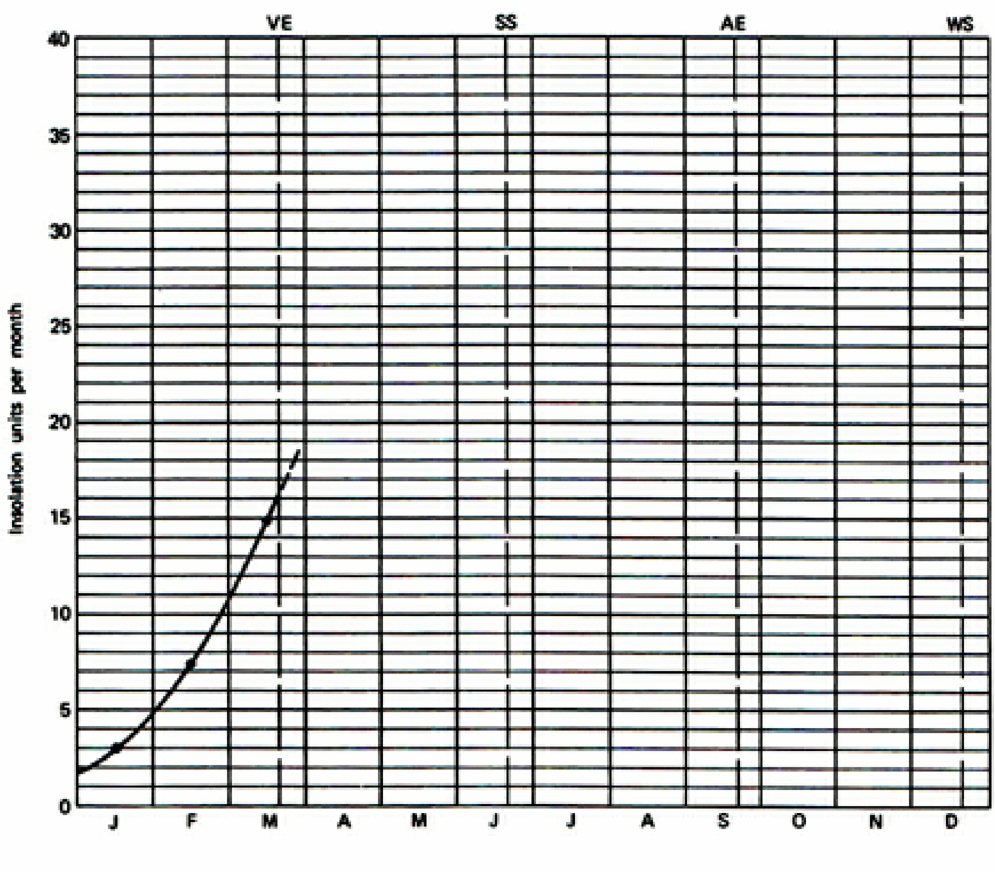
| Latitude | Jan. | Feb. | Mar. | Apr. | May | Jun. | Jul. | Aug. | Sep. | Oct. | Nov. | Dec. | Total for year |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 90 | ... | ... | 1.9 | 17.5 | 31.5 | 36.4 | 32.9 | 21.1 | 4.6 | ... | ... | ... | 145.9 |
| 80 | ... | 0.1 | 5.0 | 17.5 | 30.5 | 35.8 | 32.4 | 20.9 | 7.4 | 0.6 | ... | ... | 150.2 |
| °N 60 | 3.0 | 7.4 | 14.8 | 23.2 | 30.2 | 33.2 | 31.1 | 24.9 | 16.7 | 9.0 | 3.8 | 1.9 | 199.2 |
| 40 | 12.5 | 17.0 | 23.1 | 28.6 | 32.4 | 33.8 | 32.8 | 29.4 | 24.3 | 18.4 | 13.4 | 11.1 | 276.8 |
| 20 | 22.0 | 25.1 | 28.6 | 30.9 | 31.8 | 32.0 | 31.8 | 30.9 | 28.9 | 25.8 | 22.5 | 20.9 | 331.2 |
| Equator | 29.4 | 30.4 | 30.6 | 29.6 | 28.0 | 27.1 | 27.6 | 28.6 | 30.1 | 30.2 | 29.5 | 28.9 | 350.0 |
| 20 | 33.8 | 32.2 | 29.0 | 24.9 | 21.2 | 19.6 | 20.5 | 23.7 | 27.7 | 31.1 | 33.3 | 34.1 | 331.1 |
| 40 | 34.8 | 30.4 | 23.9 | 17.4 | 12.5 | 10.4 | 11.6 | 15.8 | 21.9 | 28.5 | 33.6 | 36.0 | 276.8 |
| °S 60 | 33.0 | 25.3 | 16.0 | 8.1 | 3.3 | 1.7 | 2.7 | 6.5 | 13.6 | 22.6 | 31.1 | 35.3 | 199.2 |
| 80 | 34.2 | 20.5 | 6.3 | 0.3 | ... | ... | ... | ... | 3.8 | 16.0 | 31.0 | 38.1 | 150.2 |
| 90 | 34.7 | 20.7 | 3.2 | ... | ... | ... | ... | ... | 1.0 | 15.6 | 31.5 | 38.7 | 145.4 |

1. Study the insolation curves in relation to the annual curve of the sun's declination. Compare times of maximum and minimum value at 60° N and 40° S. Explain how these two curves differ in timing.

2. Explain how the maximum and minimum of insolation at the equator are related to the curve of the sun's declination.




***Graph A***




***Graph B***

**Analemma**

The analemma is the geographers' tool used to locate the sub-solar point, or the point on Earth's surface where the sun is directly overhead. The subsolar point is the closest point to the Sun on the surface of the Earth. The analemma can be used for any place on earth, and any day of the year. Find January 17th on the Analemma. It's marked with a dot. It lies on the line labeled 9 minutes on the "sun slow" side. This means that the sun will reach its "noon" zenith, or highest point of the day at 12:09 PM, 9 minutes "late".

1. Use the analemma to find:
   a. the subsolar point on November 10_______________
   b. the subsolar point on May 11__________________
   c. the subsolar point today________________
   d. the date(s) when the declination is 21°N______________
   e. the date(s) when the declination is 9°S________________

2. At what clock time does the Sun actually reach zenith on:
   a. October 1?__________________
   b. March 8?___________________
   c. May 20?__________________
   d. Today?____________________

The noon sun angle changes at any given latitude throughout the year. Using the analemma to determine the subsolar point (Sun's Declination), you can calculate the altitude of the sun at noon.

- For example, calculate the solar altitude for Los Angeles (34°N) on July 16.
  - From the analemma, you can see that the solar altitude on July 16 is approximately 21°, and this is in the **same** hemisphere as the location in question.

    - Use Solar Altitude= 90°
    - 34° -21°= 13° Arc Distance
    - 90°-13° = 77° (Solar Altitude-Arc Distance=solar altitude for a particular location)
- So on July 16, the noon sun is 77° above the horizon in Los Angeles.

If the declination of the sun (on the Analemma) and the latitude of the sun (where on Earth you are calculating from) are in opposite hemispheres, add both latitudes together to determine the arc distance. To calculate the solar altitude on December 21 in Los Angeles, look at the analema for that date…23.5° in the SOUTHERN HEMISPHERE

- Since Los Angeles and the declination of the sun are in **opposite** hemispheres, add to determine the arc distance:
  - 23.5°+ 34°=57.5°
    - Then use the formula to calculate the solar altitude: 90° – 57.5°=32.5°
- So at noon on December 21 in Los Angeles, the sun is 32.5° above the horizon.

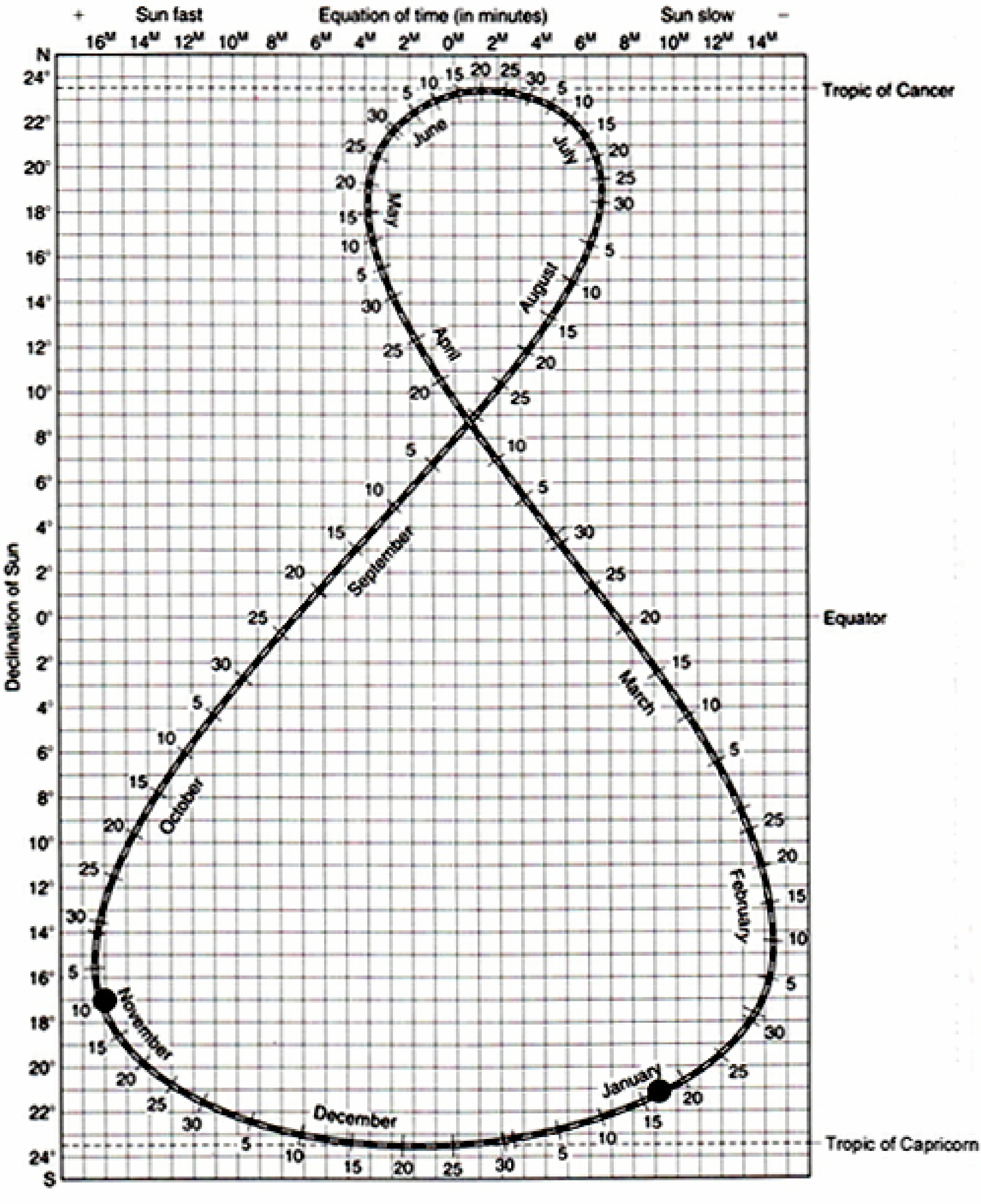
(Analemma con't)

3. Use the analemma to determine the noontime subsolar point for a give location and date.

a. 40° N on April 20 ___________________

b. 30° N on December 21 __________________

c. 10° S on July 10 _______________________




The analemma